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Beam Crossing Geometry and Their Requirements

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ABSTRACT

Beam size requirement for BC2 and BC1 at various operational conditions are calculated. This report is prepared for the magnet group to evaluate the feasibility of designing the beam crossing dipoles.

1. BEAM SIZES consideration

RHIC is designed to be able to operate in the following conditions:[1]

a. Equal species (from proton to Au) with crossing angles 0–5 mr and $\beta^* = 3 \sim 10$ m
b. Unequal species (e.g. Proton on Gold) with crossing angle 0 mr.
c. Possibly, natural crossing without BC1 at 16mr.
d. Future upgrade of mini-β insertions.
e. Special insertion for the fragmentational region physics.

The condition d shall be addressed in the future when experimentalist need more luminosity. The conditions a, b and c give constraint to the aperture of beam crossing dipoles. At present, BC1 and BC2 have 200 mm and 100 mm coil i.d.[1] respectively. We shall discuss each aspect in the following:

a. EQUAL SPECIES:

The performance is limited by the low β^* operation. At β^*=3m, the β value at the exit of the BC2 is 175 m. By taking the 2/3 rule for the large dipoles, the minimum coil i.d. requirement is 97 mm for the acceptance of emittance of 6 π-mm-mrad. Because the dispersion function is small in this region. the required momentum aperture is minimum. The small β value at the crossing point does not pose constraint to the BC2 at the end near to the crossing point. The size of the BC1 coil i.d. poses limitation of a maximum crossing angle 6 mr if the 2/3 rule also apply to BC1. Better field quality in BC1 will result larger crossing angle options for small diamond length experiments.

b. UNEQUAL SPECIES:

For unequal species operations at 0 mr crossing angle, the proton is incident through the interaction point at angle of −3.5mr and the heavy ion(Au) is making an angle of 3.5mr. Normally, the proton beam has a smaller beam size than the heavy-ion due to smaller intrabeam scattering. Using the same beam size estimate, we found that the beam size requirement becomes uniform in BC2 due to the operation of unequal species. The optimal bending radius for the BC2 is 308m, which corresponds to the orbit of 0 degree crossing of equal species.

c. POSSIBLE natural crossing:

The operational mode for the possible insertion without BC1 is yet to be studied. We calculate here however that the particle orbit in this mode also in Fig.1. Because of BC2 is bent with radius of curvature of 308m, this operation can not tolerate smaller β value at the crossing point unless a larger radius of curvature BC2 is used.

d. MINI-β insertions:

Some experiments need higher luminosity, where the quadrupoles can be located at about 4-5 m from the interaction point.[2] In this mode, it can only operate at equal species. because of the common magnets for two beams. A scheme for this option has not been finalized. A preliminary experimental configuration is needed to start a detail design. It is likely that the phase advance for this insertion will increase. To maintain the same operation tune, the phase advance of each each cell shall be reduced to accomodate this mode. Since this is one of the future option of upgrade, we shall not address the problem here.

e. FRAGMENTATION physics insertion.

The fragmentational region group is likely to have a stronger impact on the geometry of the crossing regions[3]. The detector requires a much higher field to analyze those particles with almost the same rapidity as that of the beam particles. It may require a new insertion concept or some orbit correction elements to restore the beam orbit.

2. $\pi/2$ phase advance point in the lattice at Q3-Q4

We have mentioned that the present lattice may be able to accomodate features listed in section 1(options c,d,and e need further study), there is an interesting feature which may or may not be important, i.e. the phase advance between the interaction point and the long distance(~40m free space) between quadrupoles Q3 and Q4 is approximately $\pi/2$ for both x and y planes. The corresponding kicker's arm is about 20m. Using beam pipe of 65mm , which corresponds to coil inner radius of Q1-Q4, One expects to observe particles at an angle of larger than 3.2 mr. Detail calculation is needed to access the usefulness of the feature for the experimental setup.

REFERENCES:

1. Conceptual design of RHIC, BNL-51932.

2. G. Young, private communications.

3. M. Faessler and P. Braun-Munzinger, private communications.

Appendix. Beam sizes in the crossing region at 30 GEV in 10 HOURS

The following table is based on the emittance obtained by G.Parzen by calculating the total growth due to the intrabeam scattering at 10 hour of operation. He obtains a total normalized emittance of 33π-mm-mrad for Au ion at 30 GeV. This corresponds to an emittance of 1 π-mm-mrad. The beam size is taken to be 6σ of the distribution(table 2). The radius of bending curvature for BC2 is assumed to be 308m. The actual beam size requirement is the sum of the betatron beam size and the orbit deviation due to different crossing geometry.

Table A1 β function (in meters) in the beam crossing region.

β^*(m)	β(BC1N)	β(BC1F)	β(BC2N)	β(BC2F)
3.08	35.5	60.4	115	175
5.47	23.7	37.8	68.7	102

+Notation : BC1N = near side of BC1(near to IP)
BC1F = far side of BC1
BC2N = near side of BC2
BC2F = far side of BC2

Table A2 6σ beam size at the interaction region of RHIC. where normalized emittance is assumed to 33π-mm-mrad.

β^*(m)	x(BC1N) (mm)	x(BC1F) (mm)	x(BC2N) (mm)	x(BC2F) (mm)
3.08	14.59	19.04	26.27	32.40
5.47	11.92	15.06	20.30	24.74

Table A3. Beam orbit deviation from the center of magnet as function of angle with respect to center line.

angle (rad)	x(BC1N) (mm)	x(BC1F) (mm)	x(BC2N) (mm)	distance at BC2N from center line(mm)
-0.004	-40.00	-8.19	-11.20	115.23
-0.003	-30.00	1.36	-8.40	118.03
-0.002	-20.00	10.91	-5.60	120.83
-0.001	-10.00	20.46	-2.80	123.63
0	0.00	30.01	0.00	126.43
0.001	10.00	39.56	2.80	129.23
0.002	20.00	49.11	5.60	132.03
0.003	30.00	58.66	8.40	134.83
0.004	40.00	68.21	11.20	137.63
0.005	50.00	77.76	14.01	140.43
0.006	60.00	87.31	16.81	143.23

+ 1. The angle 1 mr corresponds to 2mr beam crossing angle.
2. P+Au at 0 degree crossing corresponds to p at -3.5mr and Au at 3.5 mr in the above table.

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β_2 = 307.68 m (0 degree xing)